Regional Operational Plan SF.1J.2015.02

Production of Coho and Chinook Salmon in the Taku River, 2015

by

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April 2015

Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

REGIONAL OPERATIONAL PLAN SF.1J.2015.02

PRODUCTION OF COHO AND CHINOOK SALMON IN THE TAKU RIVER, 2015

by

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ABSTRACT

Coho *Oncorhynchus kisutch* and Chinook salmon *O. tshawytscha* smolt abundance and adult coho production will be estimated from the Taku River, above Canyon Island, near Juneau, Alaska. The estimates of smolt abundance and adult production will be realized through coded wire tag and harvest sampling programs, and an inriver adult mark-recapture experiment. A modified Petersen estimator will be used to estimate the smolt emigration in 2015. Mark-recapture studies will be used to estimate inriver runs for coho salmon in 2015. Inriver harvest will be accounted for in determining escapement estimates for coho salmon. Scale samples of coho salmon will be used for age analysis to estimate annual age compositions. Coho and Chinook salmon smolt will be systematically sampled to estimate the mean length for each species.

Key words: coho salmon, Chinook salmon, adult production, smolt production, coded wire tag, Petersen estimator, marine survival, exploitation, mark-recapture, inriver run, escapement, total run, age composition, Taku River.

PURPOSE

This operational plan details procedures for the estimation of Chinook and coho salmon smolt abundance, adult Chinook and coho salmon harvest, and coho escapement using information gathered from the coded wire tag (CWT) and adult sampling programs in 2015. Chinook salmon escapement estimation in 2015 is covered in a separate operational plan entitled “Estimation of Chinook Salmon Escapement in the Taku River.” Improved stock identification is a critical element in the strategy to improve stock assessment and management of Chinook salmon, as outlined in Attachment F to the 1996 U.S. Letter of Agreement (L.O.A), the 1999 Pacific Salmon Treaty (PST) agreement, and U.S. coastwide Chinook salmon stock assessment standards (USCTC 1997). Stock identification programs provide stock specific harvests, from which total adult production, exploitation rates, harvest distribution and survival parameters are estimated. These data are necessary for implementation and improvement in: 1) Alaska Department of Fish and Game (ADF&G) management, 2) terminal run management by the ADF&G and Department of Fisheries and Oceans Canada (DFO) and 3) coastwide management in the Pacific Salmon Commission (PSC) process. This project, coupled with estimates of Chinook escapement for the Taku River, will aid both countries in following the management directive. Production parameters such as harvest, escapement, exploitation rate, smolt production, and brood year production will be directly estimated through implementation of the smolt tagging and adult escapement projects.

The ADF&G has chosen the Taku River as 1 of the 12 statewide Chinook salmon indicator stocks.

BACKGROUND

The Taku River (Figure 1) produces the largest runs of coho salmon *Oncorhynchus kisutch* and Chinook salmon *O. tshawytscha* in Southeast Alaska (SEAK) and north of the Skeena River in British Columbia (McPherson et al. 1998; Yanusz et al. 1999). From 1992 to 2014, the estimated total run of coho salmon from above Canyon Island has averaged 185,000 fish, and the recent 5-year average has been 165,000. The terminal run of large (≥660 mm MEF) Chinook salmon has averaged 47,000 since 1995, and the recent 5-year average is 28,000. Small (≤400 mm MEF) and medium (401–659 mm MEF) Chinook salmon are not included in the above estimates and on average over the past 10 years the total terminal run consisted of 75% large, 2% small, and 23% medium-sized Chinook salmon.

Detailed stock assessment projects designed to directly estimate production parameters such as escapement, harvest, harvest or exploitation rate, smolt production, survival rates and brood year production have been in place since 1987 for coho salmon and 1995 for Chinook salmon. Both projects are ongoing cooperative programs between ADF&G and DFO in concert with the Taku River Tlingit First Nation (TRTFN). Coded wire tags were placed in coho salmon smolt captured in the mainstem Taku River beginning in 1991 (Elliott and Bernard 1994). This program was expanded to include Chinook salmon smolt in 1993 (McPherson et al. 2000), and since then both species have been marked with CWTs annually.

The Parties (i.e., U.S. and Canada) concurred on a new PST agreement in June 1999. Included in that agreement is a specific directive in Annex IV, Chapter 1 of the treaty stating that the Parties affirm their intent to develop and implement abundance-based management regimes for transboundary (i.e., Alsek, Stikine, and Taku rivers) Chinook, sockeye *O. nerka*, and coho salmon. Although directed fisheries for sockeye and coho salmon occur annually on the Taku River, no directed “spring time” gillnet fisheries had taken place between 1976 and 2005. Following a 2-year negotiation process, the Parties came to bilateral agreement at a meeting in Portland, Oregon in February 2005 to implement new directed “spring time” commercial fisheries on Taku and Stikine rivers Chinook salmon, and to continue those fisheries through the remainder of the Annex period (i.e., 2008). With the pending expiration of the Annex, renegotiation of the treaty began in 2007, and in January 2008, once again in Portland, the Parties came to bilateral agreement that directed fisheries will be continued through the next Annex period (i.e., 2009 to 2018).

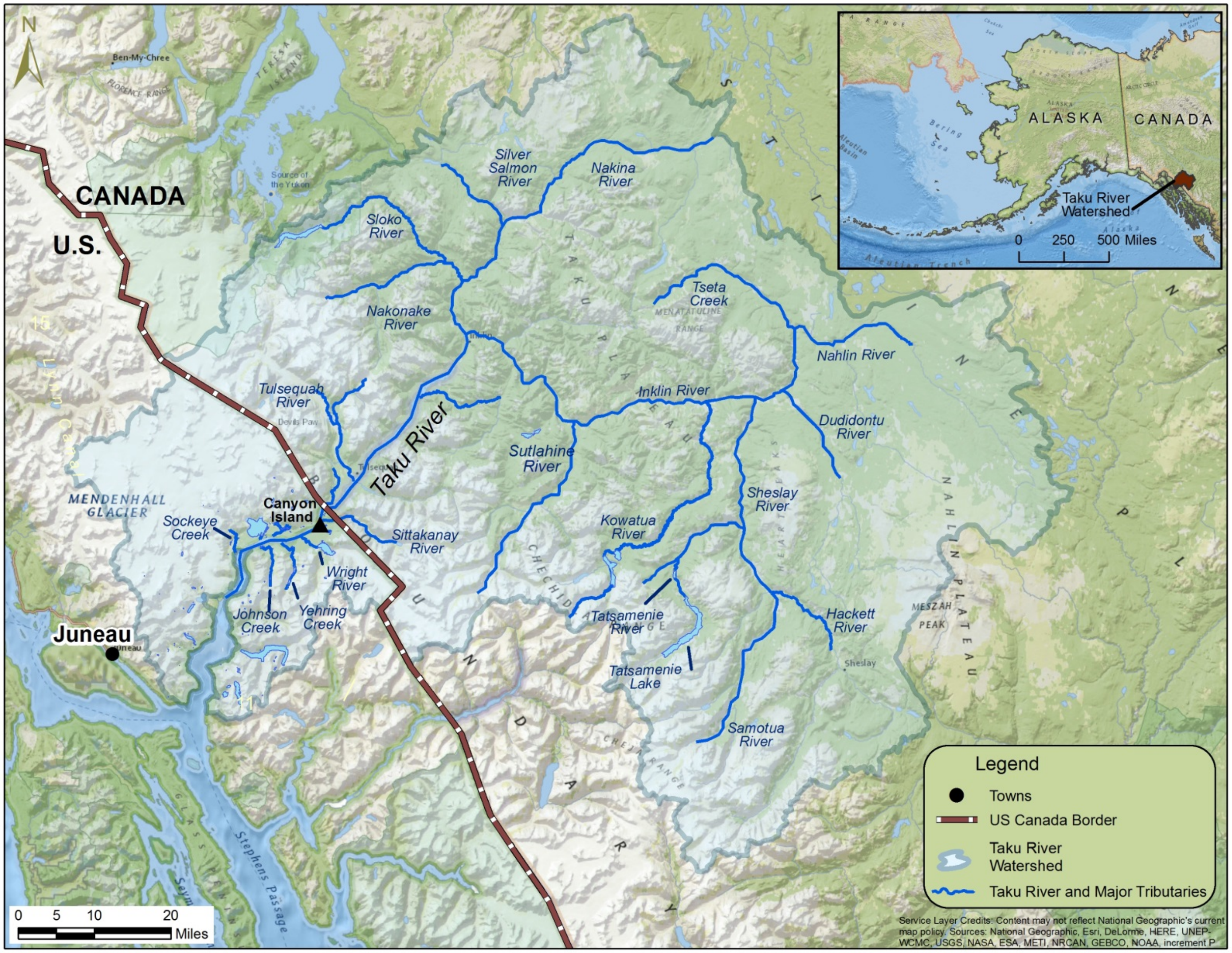

Figure 1.–The Taku River drainage of northwestern British Columbia and Southeast Alaska.

OBJECTIVES

1. Estimate the number of coho salmon smolt (≥75 mm FL) leaving the Taku River in 2015 that originated from above Canyon Island, such that the half-width of the calculated 95% confidence interval is ≤ 25% of the estimate.
2. Estimate the marine harvest in sampled salmon fisheries in 2016 of adult coho salmon that originated from above Canyon Island in the Taku River via recovery of CWTs applied in 2015, such that the half-width of the calculated 95% confidence interval is ≤30% of the estimate. This estimate will be derived from recovery of CWTs in SEAK salmon fisheries and in the Taku River in 2016.
3. Estimate the number of Chinook salmon smolt (≥50 mm FL) leaving the Taku River in 2015, such that the half-width of the calculated 95% confidence interval is ≤ 25% of the estimate.
4. Estimate the marine harvest in sampled fisheries of adult Chinook salmon from the 2013 brood year via recovery of CWTs applied in 2015, such that the half-width of the calculated 95% confidence interval is ≤27% of the estimate. This estimate will be derived from recovery of CWTs in SEAK salmon fisheries and in the Taku River from 2016 through 2020.
5. Estimate the escapement of adult coho salmon past Canyon Island in 2015 between June 15 and October 3, such that the half-width of the calculated 95% confidence interval is ≤ 20% of the estimate.
6. Estimate the age composition of adult coho salmon passing Canyon Island in 2015 between June 15 and October 3, such that the half width of the calculated 95% confidence intervals for all estimated fractions are ≤5% of their respective estimates.

SECONDARY OBJECTIVES

1. Estimate the age composition of coho salmon smolt (≥75 mm FL) captured near Canyon Island in 2015 such that the half width of the calculated 95% confidence intervals for all estimated fractions are ≤7% of their respective estimates.
2. Estimate the mean lengths of Chinook salmon smolt (≥50 mm FL) captured near Canyon Island in 2015 such that the the half width of the calculated 95% confidence intervals are within 2 mm of the estimated means.
3. Estimate the mean lengths of coho salmon smolt (≥75 mm FL) captured near Canyon Island in 2015 such that the the half width of the calculated 95% confidence intervals are within 2 mm of the estimated means.
4. Test the hypothesis that smaller coho salmon smolt (75–85 mm FL) survive at the same rate as larger smolt (>85 mm).
5. Record numbers of smolt captured by species, time, and location using the Global Positioning System (GPS).
6. Record weights of coho and Chinook salmon smolt to the nearest 0.1 g.

Calculation of the above parameters will allow us to also estimate total adult production, exploitation rates, and marine survival rates.

METHODS

STUDY DESIGN

Smolt Abundance

Separate mark-recapture experiments will be used to estimate the abundance of Chinook and coho salmon smolt emigrating from Taku River above Canyon Island in 2015 (Figure 1). Smolt will be tagged with CWTs and marked with adipose fin clips in 2015 as part of Event I of a two-event closed population mark-recapture experiment. As part of Event II, returning adult coho salmon will be inspected for a missing adipose fin in 2016, and Chinook salmon will be examined from 2016 through 2020.

Smolt trapping operations will be based out of a camp located just upstream of Canyon Island to implement the marking event (Figure 2). Approximately 150–200 minnow traps baited with salmon roe will be fished daily in the mainstem of the Taku River near Canyon Island beginning as soon as the river is open to boat and plane traffic, with a tentative startup date of Friday, April 17, 2015. Two trap lines will be set between approximately 10 km above and below the upper camp. Each trap line will be maintained by 2 personnel and will consist of 75–100 traps per trap line. Smolt from all trap lines will be transported back to camp for processing each day. Seine nets will also be used along gravel bars on the Taku River mainstem by 3-person crews to capture Chinook and coho salmon smolt to supplement minnow trap catches. When outmigration of smolt commences in early May, seining effort will increase accordingly. All healthy **Chinook smolt ≥50 mm FL** and **coho smolt ≥75 mm FL** captured each day will be tranquilized with a buffered tricaine methanesulfonate (MS-222) solution, injected with a CWT, and have their adipose fin excised. Each CWT is formed by cutting a 1.1 mm section of wire from a spool stamped with a unique numeric code and each spool contains enough wire for approximately 5,000, 10,000 or 20,000 tags. Three unique codes will be used each day, 1 for Chinook salmon and 2 for coho salmon in different size categories (75–85 mm FL; >85 mm FL), and spools will be changed only after they are completely used.

Adult coho and Chinook salmon will be sampled as they return to the Taku River. In 2015, adult coho salmon caught at Canyon Island in fish wheels and set gillnets, and during inriver test and commercial gillnet fisheries, will be inspected for missing adipose fins (June to early October). Personnel from the ADF&G Division of Sport Fish (SF) and Division of Commercial Fisheries (CF), DFO, and TRTFN Fisheries will sample these adults and record the associated data. Water current at Canyon Island is normally fast, and catch rates in the fish wheels can be high. From 1987 to 2014 an average of 2,400 (range 965 to 4,922) coho salmon were caught in the fish wheels. The marked fraction (fish missing adipose fins) of coho salmon captured in the fish wheels and gillnets in 2016 will be used to estimate smolt abundance in 2015.

Figure 2.–Location of central portion of study area on Taku River near Canyon Island, Southeast Alaska.

Similarly, adult Chinook salmon caught at Canyon Island and in the inriver test fishery will be inspected for missing adipose fins (as detailed in a separate operational plan). Given the life history of Chinook salmon, adults carrying CWTs from smolt marked in 2015 will return to the Taku River in 2016 (age-1.1 fish) through 2020 (age-1.5 fish) and, hence, will require sampling over a 5-year duration. Adult Chinook salmon are typically caught at Canyon Island from late April through mid July.

SAMPLE SIZES

Sampling targets for coho salmon smolt are based on historical precedents. Since 2001, we have captured and tagged around 1.0% of the total smolt emigration. Production has averaged 2.45 million smolt per year over that time, and 1.0% of this average is 24,500 smolt. In 2015, if we tag at least 24,000 fish and about 2,016 of those survive given an average marine survival rate of 8.6% (Jones et al. 2012), then to meet the precision criteria in Objective 1 we will need to examine 7,039 returning adults in 2016 to estimate smolt abundance in 2015 (Robson and Regier 1964). On average 2,400 coho salmon have been inspected at Canyon Island and at least another 6,000 have been examined in the inriver test and Canadian commercial fishery. Given this, an expected total of 8,400 coho salmon will be examined in 2016 and objective statements regarding coho salmon smolt estimates will be met or exceeded.

Since 1991, on average, 1.8 million Chinook salmon smolt leave the Taku River each year and marine survival averages 3.5%. Thus, about 65,000 adults will return in subsequent years from an average smolt outmigration of 1.8 million. If we mark 29,000 smolt annually, based on marking 1.6% of an average annual smolt outmigration of 1.8 million fish, then about 1,000 (3.5%) marked smolt will survive to return as adults in subsequent years. To meet objective precision criteria for each brood year, about 4,255 known-age adults will need to be sampled at the various inriver sampling locations to provide an expected 68 recaptures (Robson and Regier 1964). Because Chinook salmon return at various ages, returning Chinook salmon will be inspected for marks and scales will be collected for aging in 2016 through 2020 (age-1.1 to -1.5; European age notation) at Canyon Island, in the test and Canadian commercial fisheries, and on the spawning grounds of tributaries to the Taku River (Nahlin, Nakina, Kowatua, Tatsamenie, Tseta and Dudidontu rivers; Figure 1). Last season, about 6,000 adult Chinook salmon were inspected: approximately 1,300 at Canyon Island in fish wheels and gillnets, 3,000 in the inriver test and commercial fisheries, and about 1,500 on the spawning grounds. If about 5,000 returning Chinook salmon are inspected each year and about 95% of them are aged, then objective statements regarding Chinook salmon smolt estimates will be met or exceeded.

MODEL ASSUMPTIONS FOR ESTIMATION OF SMOLT ABUNDANCE

These two-event closed population mark-recapture experiments are designed so that a Petersen-type estimator may be used to estimate abundance. For the estimates of abundance to be unbiased, certain assumptions must be met (Seber 1982). These assumptions, expressed in the circumstances of this study, along with their respective design considerations and test procedures, are:

Assumption I: There Is No Recruitment to the Population Between Years

Considering the life histories of Chinook and coho salmon, there should be no recruitment between sampling events. Because almost all surviving smolt return to their natal stream as adults to spawn, there will be no meaningful recruitment added to the population while they are at sea (i.e., low incidence of straying).

In regards to coho salmon, the population for which abundance is being estimated is smolt produced from stock that spawn above Canyon Island. Those fish from stocks that spawn downstream of Canyon Island will not be subject to capture either as smolt or adults. Approximately 22% of adult coho salmon fitted with radio tags in 1992 near the mouth of the Taku River spawned below Canyon Island (Eiler et al. 1993). Studies on the Taku River in previous years have shown some straying of fingerlings tagged above Canyon Island to tributaries downstream. Also, some adults tagged as smolt leaving tributaries downstream of Canyon Island have been caught in the fishery upstream of Canyon Island. However, Elliott and Sterritt (1990) found that the marked fraction of smolt leaving Yehring Creek, a tributary of the Taku River below Canyon Island, was very similar to the marked fraction of returning adults. These results support our belief that the observed straying of smolt and adults past Canyon Island will be an insignificant source of potential bias when estimating abundance. Thus, it is assumed that tagged coho salmon smolt represent production from stocks that spawn above Canyon Island.

In regards to Chinook salmon, negligible numbers of fish have been observed spawning in U.S. sections of the drainage and it is believed that tagging at Canyon Island measures the vast majority of production from the Taku drainage.

Assumption II: There Is No Trap-Induced Behavior

There is no explicit test for this assumption because the behavior of unhandled fish cannot be observed. Trap-induced behavior is unlikely because different sampling gears will be used to capture smolt and adults. Results from other studies (Elliott and Sterritt 1990; Vincent-Lang 1993) indicate that clipping adipose fins and implanting CWTs does not affect the mortality of tagged salmon smolts.

Assumption III: Tagged Fish Will Not Lose Their Marks Between Sampling Events and All Marks Are Recognizable

The use of properly applied adipose fin clips will ensure that marks are not lost and that all marked fish are recognizable during second event sampling. Adipose fins will not regenerate like other fins if excised at the base. Naturally missing adipose fins on wild stocks of Chinook and coho salmon are very rare (Magnus et al. 2006). All adipose fin clipped fish will be used for estimating smolt abundance regardless of the presense of valid CWT wire.

Assumption IV: One of the Following Three Sets of Conditions on Mortality and Sampling Will Be Met:

S1) All fish have an equal probability of being captured and marked during the first event; or

S2) Complete mixing of marked and unmarked fish occurs prior to the second event, hence all fish have the same probability of surviving between events across all tagging groups; or

S3) All fish have an equal probability of being captured and inspected for marks during the second event, hence all fish have the same probability of surviving between events across all tagging groups.

Regarding S1 for the smolt to adult mark-recapture:

Both minnow traps and beach seines are used to capture smolt. Minnow traps can be size-selective, however the majority of Chinook and about half of the coho sampled are caught in beach seines which are not size-selective.

Coho salmon smolt represent at least 2 age groups and cover a range of sizes. In the past there has been size-selective sampling during the first event for coho salmon emigrating from the Taku River (Appendix A1; Jones et al. 2006), but the more recent use of beach seines should minimize the effects of size-seletivity,

Regarding S2 for the smolt to adult mark-recapture:

Due to the extended time period between the marking and recovery events and behavior of salmon between these events, it is believed that complete mixing of marked and unmarked fish occurs prior to the adult recovery events in the lower river. For coho, size-selective mortality rates have occurred in the past (Jones et al. 2006). If this is true then this assumption will not be met.

Regarding S3 for the smolt to adult mark-recapture:

Adult Chinook and coho salmon immigrations will be sampled almost continuously with fish wheels and gillnets, as well as surveys of spawning locations for Chinook salmon specifically. These methods promote equal probabilities of capture through migrations and, at a minimum, ensure that no segments of the adult immigrations have zero probability of capture during the second event. However, all Chinook salmon will not have an equal probability of being inspected for marks during Event II sampling, as not every spawning location will be sampled. For coho, size-selective mortality rates have occurred in the past. (Jones et al. 2006). If this is true then this assumption will not be met.

In summary, for Chinook, we rely on the situation that all Chinook smolt have an equal probability of capture during event 1(condition S1). For coho if there is unequal survival between tagging groups none of the three sets of conditions will be satisfied. Equal survival between the coho salmon smolt tagging groups (2 sizes) will be evaluated using contingency table analysis to test for lack of independence between tagging group and adult tag recovery rate during adult sampling (Secondary Objective 4). If no lack of independence between tagging group and adult tag recovery is detected, at least condition S2 is satisfied and Chapman's (1951) modification to the Petersen estimator will be used to estimate abundance after pooling the tag codes. If lack of independence is detected between adult tag recovery rate and tagging group, equal probability of capture during the tagging event will need to be evaluated. The catchability coefficient ($\hat{A}$) for larger to smaller smolt (equation 6; page 20) will be estimated. If the estimate of A is not significantly different from 1.0, Chapman's (1951) formula will be used to estimate abundance as described above. Otherwise, the modified estimator (equation 4; page 19) will be used to provide an unbiased estimate (see Data Analysis; Appendix A1). Past use of this estimator has increased the coefficient of variation of the estimate modestly (about 2.5 percentage points).

MEAN LENGTH OF CHINOOK SALMON SMOLT

A systematically drawn sample of 200 Chinook salmon smolt $\geq$50 mm FL will be collected. This meets the required 78 ($[(1.96)(9)/(2)]^2 = 77.8$) needed to meet the criteria in Secondary Objective 2 (Thompson 2002, p. 36). This assumes a standard deviation of 9 mm as seen in past studies. Only

Chinook salmon smolt $\geq$50 mm FL are considered for sampling as smaller fish are more difficult to handle and have a higher probability of being fingerling fish that will remain in the river for another year. Based on an expected catch of 29,000 Chinook smolt, every 145th Chinook salmon smolt should be measured for length and weight. However, to ensure meeting our sampling targest in the event less than 29,000 fish are captured, and for ease of tracking, we will measure every 100th Chinook salmon smolt captured.

AGE COMPOSITION AND MEAN LENGTH OF COHO SALMON SMOLT

A systematically drawn sample of 250 coho salmon smolt ≥75 mm FL will be collected, exceeding minimum sample sizes needed to meet criteria for Secondary Objectives 1 and 3. Only coho salmon smolt $\geq$75 mm FL will be considered for sampling as smaller fish are more difficult to handle and have a higher probability of remaining in the river for subsequent years. For the two size groups, a sample of 196 is sufficient to meet criteria for estimating the proportions in the age composition (Thompson 2002). Because on average 10% of scale samples are unusable, sample size will be increased to at least 218 (=196/0.90). When estimating mean length of coho smolt, if the standard deviation of fork length in the population is $\leq$12 mm (the standard deviation observed in previous years), 139 samples are required ($[(1.96)(12)/2])^2 = 138.3$, Thompson 2002, p. 36). Based on an expected catch of about 24,000 coho salmon smolt, scale samples, length, and weight measurements need to be taken from every 96th coho salmon smolt to achieve a systematic sample of 250. However, in the event we capture less than 24,000 fish, we will measure every 80th coho salmon smolt captured.

GLOBAL POSITIONING SYSTEM AND TEMPORAL AND SPATIAL DATA COLLECTION

Handheld GPS units will be used to capture smolt observation data by identifying latitude and longitude for specific areas trapped and the numbers of fish collected over time (Secondary Objective 1) following protocols outlined in Nichols et al. (2013).

HARVEST OF COHO SALMON

Recovery of tagged and marked adults in the various fisheries will be used to estimate harvest of coho salmon (originating above Canyon Island) in marine fisheries in 2016. To meet the criteria in Objective 2 (95% relative precision (RP) = ±30%), approximately 24,000 coho salmon smolt need to be tagged in 2015 according to procedures in Bernard et al. (1998). This is based on inspecting at least 20% of the anticipated harvest in the various commercial and sport fisheries (Anne Reynolds, fishery biologist, ADF&G-CF, Douglas, personal communication 2015; Mike Jaenicke, fishery biologist, ADF&G-SF, Douglas, personal communication 2014).

Harvest data (Appendix A2) presented from 2014 is used to show that objective criteria can likely be met with 24,000 smolts being tagged. Assuming 926,000 coho salmon smolt outmigrate in 2015, we anticipate 65 random fishery recoveries of CWTs in 2016. Thus, we feel confident that a nearly unbiased estimate of harvest will occur if 24,000 or more coho salmon smolt are CWT tagged in 2015.

HARVEST OF CHINOOK SALMON

Chinook salmon from the Taku River are mostly (i.e., 95% to 100%) age-1. fish, spending 1 year as fry in fresh water and emigrating as smolt in the following spring (McPherson et al. 2000; Olsen

1992). Thus, all tagged (and un-tagged) smolt are essentially from the same brood year (e.g., Chinook salmon smolt tagged in 2015 are from the 2013 brood year). Unlike coho salmon that return to spawn after 1 year at sea, Chinook salmon return as adults after 1 to 5 years at sea.

Recovery of CWT-tagged Chinook salmon in the various SEAK fisheries through 2020 will be used to estimate the total marine harvest (exploitation) of Chinook salmon from the Taku River for the 2013 brood year. To meet the criteria in Objective 4 (95% RP = ±27%), 29,000 or more Chinook salmon smolt need to be CWT-tagged in 2015, according to procedures in Bernard et al. (1998). This judgment is based on historical inspection of 40% of marine commercial and sport harvests from April through June, an estimated 1.8 million smolt leaving the Taku River in 2015, an ocean survival rate of 3.5% and a marine exploitation of about 20%. Note the marine harvests will be added to inriver harvests from Canada fisheries to estimate total harvest in a calendar year, and both will be apportioned by age to estimate total adult harvest and exploitation by brood year.

A simulated data set to anticipate U.S. marine harvest from the 2013 brood is shown in Appendix A3 and is based on the above-mentioned numeric and sampling assumptions and past recoveries of Taku River CWTs from the 1975–1981 and 1991–1995 broods. Only spring strata in the marine fisheries were included in the simulated data set because historical CWT recoveries (1978–1986 and 1993–2005) indicate there is little exploitation of this stock during other times of the year (Hubartt and Kissner 1987; McPherson et al. 2000) and the inriver fisheries are known to be 100% Taku River stock in origin. The historical data indicate that on average, few harvests of age-1.1 and age-1.5 fish occur, so we ignored these age classes for planning purposes. We assumed the average U.S. exploitation rate of 15% as seen since the implementation of directed fisheries in 2005. We further assumed the average Canadian exploitation rate of 12% as seen during this same period. Thus, simulations suggest that 61 random CWTs will be recovered in the various marine commercial and recreational fisheries of SEAK. Based on methodology in Bernard et al. (1998), the probabilities of recovering at least 1 tag in each individual stratum varied from 63% to 99%. The product of the probabilities for all 23 strata listed in Appendix A3 indicates a 97% chance of not recovering a tag (risk) in every one of the strata. The risk of not getting at least 1 CWT in each of the troll strata was 20%. The odds of finding at least 1 CWT in each of the sport and gillnet strata was 40% and 11%, respectively. Overall, for the strata producing 90% of the anticipated harvest, there is a 0.36 probability of recovering at least 1 CWT in all of these strata. <u>Thus, we feel confident that a nearly unbiased estimate of harvest will occur if 29,000 or more Chinook salmon smolt are CWT tagged in 2015</u>.

COHO SALMON ESCAPEMENT AND AGE COMPOSITION AT CANYON ISLAND

All groups will cooperatively conduct a mark-recapture experiment to estimate the number of adult coho salmon returning past Canyon Island between June 15 and early October 2015. Personnel of ADF&G and TRTFN will capture coho salmon in two fish wheels at Canyon Island, where one wheel is positioned on each bank of the river. The wheels will be operated continuously and a new aluminum 2-basket design has been implemented to enable fish wheels to turn during periods of low flows, which occur in late fall. Kelley et al. (1997) and Kelley and Milligan (1997) further describe these project details. If fish wheels are inoperative for more than 2 consecutive days, gillnets (12 ft x 100 ft, 5 1/8 in mesh) will be used to capture coho salmon at Canyon Island during the hiatus. Coho salmon will be carefully removed from the fish wheels or gillnets and placed into a trough filled with water. All healthy coho salmon ≥350 mm MEF caught in either fish wheels or gillnets will be measured, examined to determine sex, inspected for missing adipose fins, and tagged with a length of plastic "spaghetti" tubing imprinted with an individual number sewn through the dorsal musculature just below the posterior portion of the dorsal fin. Some fish will also be sampled for scales if they meet the criteria below. All fish will be released at the site of capture. Past studies on coho salmon have shown that the loss of spaghetti tags between the marking site at Canyon Island and the recapture area located just upriver above the border is rare, so no secondary mark will be added to tagged fish. Additionally, the loss of the primary spaghetti tag has been viewed as inconsequential as fish are normally recovered within 3 weeks of tagging and tagging scars are still visible and serve as a secondary mark (Yanusz et al. 1999). Recovery of tags from the commercial fishery is through return by fishermen (a condition of each fishing permit) and past studies have shown that all tags are likely returned (Kelley et al. 1997). A $5 (Canadian) reward for each recovered tag will be paid by DFO as additional incentive to report tags. Operation of the fish wheels or gillnets will end in early October or when daily catches have dwindled to near zero.

An estimated 1.7 million coho smolt will emigrate from the Taku River in 2015. This estimate was obtained through simple linear regression of the historical smolt abundance and the CPUE (i.e., 1.43 coho smolt per trap check) seen during the minnow trapping effort in 2014. In total, 4,964 coho smolt were marked with CWTs in 2014. Applying the 10-year average (2005-2014) marine survival of 9.6% to the total estimated 1.7 million smolt outmigration results in a forecasted total run of about 160,000 fish. Assuming this forecast is accurate and applying an average U.S. marine exploitation rate of 37%, then about 100,00 of those fish should pass Canyon Island. Since 1987, the fish wheels have caught about 3.5% of the coho salmon that pass Canyon Island. Thus, we predict about 3,500 adult coho salmon will be marked with spaghetti tags and released at Canyon Island in 2015. In order to meet objective precision criteria (i.e., the calculated half-width of the 95% confidence interval is within 20% of the estimate), 2,800 adult coho salmon must be inspected upriver in the test and Canadian commercial fisheries as part of Event II (Robson and Regier 1964). According to the treaty, if the above-border run size exceeds 60,000 coho salmon, a directed Canadian harvest of at least 7,500 coho salmon is allowed. Thus, we anticipate that about 2,500 and 5,000 will be harvested and inspected in the inriver test and Canadian commercial fisheries, respectively, and the objective criteria will be met.

Based on a population of 99,000 and a scale regeneration rate of 20%, a systematically drawn sample of 636 adults must be sampled using procedures in Thompson (1987) to satisfy the precision criteria of Objective 6. If at least 2,000 fish are captured at Canyon Island, then every 3rd coho salmon caught will need to be sampled for scales. Approximately 3,500 are expected to be captured, so a sampling rate of 1/3 will allow us to easily exceed the minimum sample size. The estimates should be unbiased even if the sampling gear is size selective; the differences in age composition for Taku River coho salmon reflect differences in freshwater age, and there is no relationship between freshwater age and the size of adult coho salmon. Personnel from DFO will sample fish for tags, age, and size in the inriver test and Canadian commercial fisheries from July into early October. Scales will be taken from the preferred area (i.e., the left side of the fish; 2 rows up from the lateral line on an imaginary line from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin; Scarnecchia 1979). Four scales will be taken from each fish and mounted on gum cards for later impression into acetate cards using a scale press. Ages will be determined from patterns of circuli according to protocols in Mosher (1968) and the CF scale-aging group.

MODEL ASSUMPTIONS FOR ESTIMATION OF COHO SALMON ESCAPEMENT

This two-event closed population mark-recapture experiment is designed so that a Petersen-type estimator may be used to estimate abundance. For the estimate of abundance to be unbiased, certain assumptions must be met (Seber 1982). These assumptions, expressed in the circumstances of this study, along with their respective design considerations and test procedures, are:

Assumption I: The Population Is Closed to Births, Deaths, Immigration and Emigration

Considering the short distance between Canyon Island and the inriver fisheries just upstream, emigration (from births or outmigration) is consider neligible. Considering the life history of the species, there should be no recruitment between sampling events. First event sampling (marking) will begin prior to any significant passage of fish past the tagging sites and will continue through the run until passage has dropped to near zero.

Assumption II: There Is No Trap-Induced Behavior

There is no explicit test for this assumption because the behavior of unhandled fish cannot be observed. There should be no trap-induced behavior because different sampling gears are used in different sampling events. However, we will attempt to meet this assumption by minimizing holding and handling time of all captured fish. Any obviously stressed or injured fish will not be tagged.

Assumption III: Tagged Fish Will Not Lose Their Marks Between Sampling Events and All Marks are Recognizable

Past studies on coho salmon have shown that the loss of spaghetti tags between the marking site at Canyon Island and the recapture area located just upriver above the border is rare, so no secondary mark will be added to tagged fish. Additionally, the loss of the primary spaghetti tag has been viewed as inconsequential as fish are normally recovered within 3 weeks of tagging so tagging scars will serve as a secondary mark.

Assumption IV: One of the Following Three Conditions Will Be Met

1. All coho salmon will have the same probability of being caught in the first event, or
2. All coho salmon will have the same probability of being captured in the second event; or,
3. Marked fish will mix completely with unmarked fish between samples.

In this experiment, it is unlikely that marked and unmarked fish will mix completely. Fish wheels will be operated continuously during the run. However, experience has shown that probabilities of capture of coho salmon change as their annual migration progresses. Fluctuations in water levels at Canyon Island can affect the efficiency of fish wheels and gillnets (Yanusz et al. 1999). Also, the change from the commercial fishery to a test fishery halfway through the migration affects the probabilities of capture during Event II, although in some years most of the sample is derived from the test fishery.

Equal probability of capture will be evaluated by time, area, size, and sex. The procedures to analyze sex and length data for statistical bias due to gear selectivity are described in Appendix A4. If different probabilities are indicated, abundance estimates will be stratified within size groups.

To further evaluate the three conditions of this assumption, contingency table analyses recommended by Seber (1982) and described in Appendix A5 will be used to detect significant temporal or geographic violations of assumptions of equal probability of capture. Based on previous experience, it is anticipated temporal violations of these assumptions will be detected, and a Petersen-type model would yield a biased estimate. Therefore, abundance will most likely be estimated according to models developed by Darroch (1961) for a two-event mark-recapture experiment on a closed population when temporal or spatial distributions of fish affect their probabilities of capture.

DATA COLLECTION

All healthy Chinook salmon smolt ≥50 mm FL and all coho salmon smolt ≥75 mm FL captured near Canyon Island without marks will be tranquilized with a buffered MS-222 solution, tagged with a CWT (Table 1) following procedures described in Koerner (1977), given an adipose fin clip, and then released. Note that all tagged fish of both species will be held overnight to test for post-tagging mortality and a portion will be tested for tag retention. Any smolt captured possessing an adipose fin clip prior to tagging will be tested for the presence or absence of a CWT (i.e., passed through a magnetic tag detector) and recorded as positive or negative.

Table 1.—Separate CWT codes to be used for tagging Chinook and coho salmon in the Taku River, Southeast Alaska in 2015.

Species[a]	Spool Size	Tag Code
Chinook	20K	04-34-98
Chinook	10K	04-10-20
Coho (small)	10K	04-13-80
Coho (small)	10K	04-15-22
Coho (large)	10K	04-30-68
Coho (large)	10K	04-35-68

[a] Small coho salmon are 75–85 mm FL and large coho salmon are greater than 85 mm FL.

Codes used will be recorded on the **CODED WIRE VERIFICATION** form obtained from the CF Mark, Tag, and Age Laboratory (CF Tag Lab); a short section of each spool of coded wire <u>will be taped to the form the first day of tagging with a new tag code</u>. All tag and recapture data will be recorded daily on the form entitled **CWT DAILY TAGGING FORM** (Appendix B1). Environemental conditions will be recorded daily on the form entitled **DAILY ENVIRONMENTAL CONDITIONS** form (Appendix B2). A new **CWT DAILY TAGGING** form will be filled out for each day of operation and for each species. Daily procedures will be as follows:

1. Record location, date, and species.
2. Record water and air temperature (Min-Max) to nearest 1°C, water depth. Data should be collected at 0800 hours each day.

3. At 0700–0730 hours mix the fish in the holding net pen for each tag code, then net and check 100 fish from each holding pen for tag retention and record this information on the **CWT DAILY TAGGING** form. If tag retention is 98/100 or greater, empty the net pen of all smolt making sure to count and record all mortalities. Next, transport the smolt to the release site and release all fish. If tag retention is less than 98/100, reprocess the entire batch of smolt in the net pen and retag any that test negative for CWTs. Examine any mortalities for proper tag placement and adjust the head mold if necessary. Check the position of the bevel on the needle and the sharpness of the needle. Reposition, sharpen, or replace the needle if necessary.
4. Check the minnow trap lines and transport all fish to camp for processing. Salmon smolt will be sorted by species and also by size for coho salmon (75–85 mm FL; >85 mm FL). Inspect each live fish and count the number possessing adipose fin clips; record the number of fish with adipose fin clips under "Recaptures" on the **CWT DAILY TAGGING FORM**. Test all recaptures for tag retention. Record results of tag retention on the **CWT DAILY TAGGING** form.
5. For all unmarked fish, apply a CWT and test for a positive reading using a tag detector. If rejected by the detector, retag. Keep an accurate <u>tally of all retags on a hand counter.</u> Write the beginning and ending machine numbers on the form and record retags, mistags, and practice tags. Show your calculations for the number of tags used for each tag code daily.
6. Systematically select every 80th coho salmon from combined catches and measure FL to the nearest whole millimeter, weigh to nearest 0.1 g, collect scales, and record date, length and weight. Record the total number of coho salmon recaptured. Measure and record FL to nearest whole millimeter and weight to nearest 0.1 g for every 100th Chinook salmon smolt captured.

ADF&G CWT ONLINE RELEASE maintained by the CF Tag Lab will be filled out after at the end of the tagging season. Information in this database will be used to estimate the number of smolt retaining CWTs. <u>A 5 cm length of coded-wire will be attached to the **CODED WIRE VERIFICATION**</u> form to verify the tag codes. If one roll of coded wire is depleted during a tagging session, a new **CWT DAILY TAGGING** form will be filled out, and a piece of wire from the new spool will be attached to the **CODED WIRE VERIFICATION** form.

For coho salmon smolt sampled for length, weight, and age, 12–15 scales will be removed from the preferred area (Scarnecchia 1979) on the left side of the fish. Scales from up to four fish will be sandwiched between two 1 in x 3 in microscope slides, and the slides will be taped together with frosted scotch tape. The length of each fish will be written in the corners of the tape portion that correspond to the location of individual fish scales on each slide (Figure 3). Location, species, and date will also be recorded on each slide. Length and weight data for each fish will be recorded on a **SALMON SMOLT LENGTH, WEIGHT, AND SCALE SAMPLES** form (Appendix B3). Additional instruction includes:

1) Do not tape over any scales;
2) Make sure scales are put in the designated area for each fish;
3) Always number each slide at its top;
4) Always record the initials of the sampler under the slide number; and

5) Clean the scales and spread them out so that they are separated and align them as shown in Figure 3.

For sampling adult salmon, river stage, water temperature, fish wheel RPM, the hours of fish wheel operation (each fish wheel), and hours of gillnet fishing time will be recorded daily on a **FISHING EFFORT** form (Appendix B4). Fish wheel catches will be checked two or more times daily, and the numbers of fish caught and tagged will be recorded on a **WHEEL SAMPLING PERIOD** form (Appendix B5). When the fish wheels are not operational, gillnets will be fished about 6 hours per day and catches will also be recorded on the **WHEEL SAMPLING PERIOD FORM**. For coho salmon, each spaghetti tag number released, date released, fish length, and sex will be

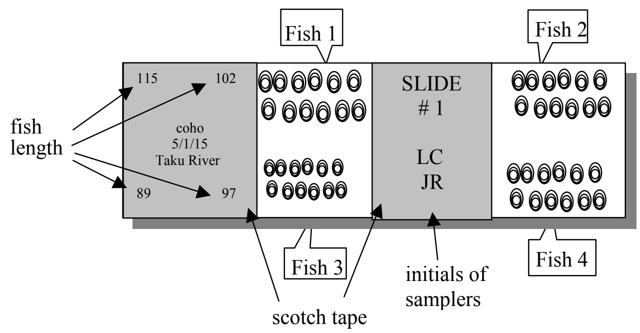

Figure 3.–Preferred microscope slide layout for coho salmon smolt scale samples.

recorded on **MARK-SENSE** forms (ADFG 1996[1]; available from Mike Jaenicke, fisheries biologist, ADF&G-SF, Douglas). Dates and tag numbers of adult coho salmon released with spaghetti tags will be relayed daily to the SF project biologist. During spaghetti tag recovery in Canada, commercial or test fishing effort (boats and days open), total catch, fish examined, lengths of fish examined, and individual tag numbers recovered will be relayed weekly by the DFO project biologist to the SF project biologist. When fish wheels are operating marginally, then gillnets will be fished about four hours per day.

Completion of smolt population and harvest estimates requires sampling the Chinook and coho salmon escapements for CWTs in succeeding years. All of the coho salmon and part of the Chinook salmon escapement sampling will be done at Canyon Island using fish wheels and gillnets. A **HATCHERY RACK AND ESCAPEMENT SURVEY** form provided by the CF Tag Lab will be completed for each sample day (fish wheel or gillnet) to document the number of fish examined and the number of fish possessing adipose fin clips. Scale samples, length, and sex will be taken from every Chinook salmon and from every third coho salmon examined. Heads will be taken from all adult coho and Chinook salmon that possess adipose fin clips, and a uniquely-numbered cinch strap will be attached to each head. Capture site, date, gear, fish sex and length (MEF), clip quality, and sample and head number (i.e., cinch strap number) will be recorded on the **HATCHERY RACK AND ESCAPEMENT SURVEY** form.

1 ADFG (Alaska Department of Fish and Game). *Unpublished*. Length, sex, and scale sampling procedure for sampling using the ADF&G adult salmon age-length mark-sense form version 3.0, Alaska Department of Fish and Game, Region I, Commercial Fisheries, June 1996.

A scale sample will also be taken from every adult Chinook or coho salmon possessing adipose fin clips, as described above, and cross-referenced to the sample data using the cinch strap number. Each head and associated data will be shipped to Juneau in specially labeled coolers on the next available flight. The Douglas office will be notified prior to each head shipment, and Douglas staff will transport the heads and associated data forms to the CF Tag Lab.

Following protocols outlined in Nichols et al. (2013), GPS waypoints will be taken at all locations where minnow traps have been placed (i.e., one GPS waypoint for every trap), except in the following circumstances:

1. any traps placed within 20 m of each other should have one and only one GPS waypoint captured (this minimizes field crew time as well as accounting for GPS positional error, which may be in the 15 to 20 m range)
    a. in these instances, crews should identify the TOTAL number of traps that fall into this 20 m proximity range, so that estimates of catch and effort are accurately recorded.
2. any traps that are NOT moved after initial GPS waypoint capture, but continued to be 'fished'
    a. in these circumstances, simply record the initial GPS waypoint number

On the **GPS DATA AND JUVENILE CAPTURE** form (Appendix B6), capture and record the following data components for each GPS waypoint recorded:

a. Date
b. Recorder/field crew members
c. GPS waypoint number
d. GPS positional error/accuracy (in meters)
e. # of traps associated with the waypoint (follow guidelines in 1a-i above)
f. Name of trapping area (site) associated with the trap(s)
g. Effort (number of days the trap was actively 'fishing')
h. Catch (number of fish captured), by species if multiple species are captured
i. Habitat (optional) – this information is NOT required, but if time and resources allow, this information should be recorded. Identify slow and fast water habitat to MACRO (pool OR fast water) and MESO habitat category (glide, riffle, OR cascade), using data provided below for additional guidance.

Macro	Meso
Pool	Backwater (BW) - eddy Scour - plunge, lateral, mid-channel Slough[a]
Fast water	Glide[b] (gradient 0–2 percent); little surface disturbance Riffle[c] (gradient 2–4 percent) Cascade (gradient > 4 percent) with emergent channel bed

[a] Slough - a section of an abandoned (temporally, seasonally, intermittently) river channel containing stagnant water and occurring on a flood plain or delta.

[b] Glide - Very low velocity stream flow that creates a calm surface condition with water flowing smoothly and gently.

[c] Riffle - shallow rapids in an open stream, where the water surface is broken by waves caused by wholly or partially submerged obstructions.

DATA REDUCTION

The field crew leader will record and error-check all data. Data forms will be kept up to date at all times. Data will be sent to the Douglas office at regular intervals and inspected for accuracy and compliance with sampling procedures. Data will be transferred from field notebooks or forms into Microsoft Excel™[2] spreadsheet files. When input is complete, data lists will be obtained and checked against the original field data.

Electronic data files will be used to check tagging totals with field notebooks, to identify lengths less than prescribed guidelines, sampling rates for age and length, and for data on the **CWT DAILY TAGGING** and **HATCHERY RACK AND ESCAPEMENT SURVEY** forms. Completed **CODED WIRE VERIFICATION** and **HATCHERY RACK AND ESCAPEMENT SURVEY** forms will be sent to the CF Tag Lab in Juneau where all CWT information for ADF&G statewide is compiled and stored. Each year Alaskan CWT data are shared with the Pacific States Marine Fisheries Commission who maintains a permanent and standardized coastwide CWT database.

Adult salmon catches, numbers tagged, and those possessing adipose fin clips will be tabulated daily by species. The number of adult salmon, length, and scale samples will be compared to the fish wheel and gillnet catches to determine if sampling protocol was followed. Spaghetti tag numbers and release dates will be compared against recoveries to locate and resolve nonsensical values. Spaghetti tag releases and recoveries will be tabulated by statistical week.

When the reports are completed, electronic copies of the data will be sent to ADF&G-SF Research and Technical Services (RTS) in Anchorage for archiving, along with a data map. Smolt data (date, age, length and weight) will be provided. All other data (CWT tag and release, adult CWT, adult age-sex-length) will be formatted and transferred to SF or CF permanent databases in Region I, ADF&G.

DATA ANALYSIS

Smolt Abundance

In the mark-recapture experiment to estimate the abundance of Chinook salmon smolt, Event II is spread over a period of 5 years. Samples of Chinook salmon will build annually that describe marked fractions by brood year over the five age classes of return (e.g., in 2016, only age-1.1 fish, as determined from scale analysis, will be used to estimate smolt abundance in the previous year; in 2017, estimated smolt abundance will be further strengthened with the addition of age-1.2 fish, and so on). The ratio estimator described by Seber (1982, sec 3.4.1) will be used to estimate abundance of Chinook salmon smolt:

$$\hat{S}_{Ch} = \frac{M}{R_{\Sigma}/C_{\Sigma}} \tag{1}$$

where $\hat{S}_{Ch}$ is estimated abundance of Chinook salmon smolts in 2015 and M is the number of marked smolt released alive into the population in 2015. Also

[2] This and subsequent product names are included for a complete description of the process and do not constitute product endorsement.

$$R_{\Sigma} = \sum_{i=1}^{y} R_i \text{ and } C_{\Sigma} = \sum_{i=1}^{y} C_i \quad (2)$$

where C_i is the number of known-age adult Chinook salmon inspected for marks in return year i from the age class that smolted in 2015, R_i is the number of fish in C_i with missing adipose fins, and y indicates the number of return years accumulated to date (e.g., 1 indicates 2016, 2 indicates 2017, etc.).

An estimate of the variance for $\hat{S}_{Ch}$ will be obtained through bootstrapping (Efron and Tibshirani 1993) similar to methods in Buckland and Garthwaite (1991) but adjusted for the ratio estimator. The fate of the estimated $\hat{S}_{Ch}$ in the experiment will be divided into capture histories (Table 2) to form an empirical probability distribution (*epd*). A bootstrap sample of $\hat{S}_{Ch}$ will be drawn from the *epd* with replacement. From the resulting collection of resampled capture histories, M^*, R_i^*, and C_i^* will be calculated. Then, from the year y (for y >1) paired values R_i^*, and C_i^* a bootstrap sample of size y will be drawn, resulting in R_i^{**} and C_i^{**}. The values M^*, R_i^{**}, and C_i^{**} will be used to calculate a bootstrap value for $\hat{S}^*_{Ch,b}$. A large number (B) of bootstrap samples will be so drawn. The approximate variance will be calculated as:

$$\hat{\mathrm{var}}(\hat{S}_{Ch}) = \frac{\sum_{b=1}^{B} (\hat{S}^*_{Ch,b} - \hat{\bar{S}}^*_{Ch})^2}{B-1} \quad (3)$$

where $\hat{\bar{S}}^*_{Ch}$ is the average of the $\hat{S}^*_{Ch,b}$.

Table 2.–Fates of $\hat{S}_{Ch}$ Chinook salmon in the mark-recapture experiment.

$M - R_{\Sigma}$	Marked	and never seen again (up to year *y*)
R_i	Marked	and recaptured during Event II in year *i (i=1 to y)*
$C_i - R_i$	Unmarked	and inspected during Event II in year *i (i=1 to y)*
$\hat{S}_{Ch} - M - C_{\Sigma} + R_{\Sigma}$	Unmarked	and never seen

The mark-recapture experiment based on coho salmon smolts and returning adults was designed to use Chapman's modification of the Petersen Method (Seber 1982) to estimate abundance of 2015 smolts. If diagnostic tests indicate that necessary assumptions for unbiased estimation are satisfied, the Chapman (1951) model will be used to estimate abundance. Variance will be estimated using bootstrapping techniques similar to what is described below for a Chapman model for estimating adult coho abundance.

If the null hypothesis of independence is rejected between adult tag recovery rate and tagging group, and between sampling events and occurrence of freshwater age of fish at smolting from the Taku River, a weighted variant of Chapman's modification to the Petersen estimator will be used to estimate abundance:

$$\hat{S}_{co} = \frac{(\hat{A}M_1 + M_2 + 1)(C+1)}{\hat{A}(R_1 + \hat{\pi}R_3) + R_2 + (1-\hat{\pi})R_3 + 1} - 1 \quad (4)$$

where M_i is the number of smolts marked by size group (1 = 70–85 mm FL, 2 = >85 mm FL) in 2015, C the number of adults in 2015 inspected for marks, R_i the subset of C with marks representing a size group of smolts (3 = group unknown), A is the ratio of the catchability coefficients for larger (>85 mm FL) to smaller (≤ 85 mm FL) smolt in 2015, and π is the fraction of adults in 2016 that were smolts 70–85 mm FL in 2014. The estimate A is used to adjust for differences in catchability in 2015 such that A > 1 when larger smolt are more catchable, and <1 when larger smolt are less catchable. Because some recaptured fish are not sacrificed to find tags or some marked adults do not contain tags, π is used to assign recaptured fish of unknown pedigree to the appropriate smolt size group. An estimate of π is:

$$\hat{\pi} = \frac{T_1}{T_1 + T_2} \quad (5)$$

where T_i is the number of all tags representing a smolt size group recovered or recaptured from adult salmon regardless of how or where recovered or recaptured.

Evidence for smolts not having equal probability of being marked regardless of size can be found through calculations based on estimates of relative freshwater age composition of smolts and adults. If $\hat{p}$ is the estimated fraction of all <u>adults</u> that are of age 1-freshwater, if $\hat{\phi}_1$ is the estimated fraction of <u>smolts</u> in the smaller-size group that were age 1-freshwater, and if $\hat{\phi}_2$ is the estimated fraction of <u>smolts</u> in the larger-size group that were age 1-freshwater, an estimate of the ratio of catchability coefficients for larger to smaller smolt is (see Appendix Addendum A1.1 in Appendix A1 for derivation):

$$\hat{A} = \frac{T_2(\hat{\phi}_2 - \hat{p})}{T_1(\hat{p} - \hat{\phi}_1)}. \quad (6)$$

An estimate of the sampling variance of $\hat{A}$ will be obtained through bootstrapping (Efron and Tibshirani 1993). Bootstrap replicates of T_1 and T_2 will obtained using the multinomial model described in Appendix A1, and bootstrap replicates of $\hat{p}$, $\hat{\phi}_1$, and $\hat{\phi}_2$ will be obtained using 3 independent binomial models based on the sample statistics use to estimate these three parameters. Equation 6 will be used to calculate a large number of bootstrap samples of $\hat{A}$ and a formula similar to equation 3 will be used to estimate the sampling variance of $\hat{A}$.

A description of the application of equations 4–6 is provided in Appendix A1, as well as a description of the bootstrap procedures used to estimate variance.

Harvest

Methods described in Bernard and Clark (1996, their Table 2) will be used to estimate the marine harvest of Chinook and coho salmon from the Taku River annually using a stratified catch sampling program of marine commercial and sport fisheries. Commercial catch data for the analysis will be summarized by ADF&G statistical week and district (for gillnet and seine fisheries), or by period and quadrant for troll fisheries (similar to Clark et al. 1985).

Sport harvest estimates from ADF&G Statewide Harvest Survey reports (e.g., Jennings et al. 2011) will be apportioned using information from sampled marine sport fisheries to obtain estimates of total harvest by biweek and fishery. Sport fish CWT recovery data will be obtained from CF Tag Lab reports and summarized by biweek and fishery (e.g., biweek 16 during the Sitka Marine Creel Survey) to estimate contribution. In most cases, CWTs of interest may be recovered in only a few of the sport fish sampling strata that defined the fishery biweek. Assuming that the harvests of fish with CWTs of interest are independent of sampling strata within fishery biweeks, harvests and sampling information will be totaled over the fishery biweek to estimate contributions.

The estimates will be based on the:

1) The fraction of the cohort marked;
2) number of coho or Chinook salmon harvested;
3) fraction of the harvest inspected for the presence of adipose fin clips;
4) number of coho or Chinook salmon in the sample possessing adipose fin clips;
5) number of sacrificed fish whose heads reached the CF Tag Lab;
6) number of these heads that contained coded wire;
7) number of these valid, legible coded wire that were decodable; and
8) number of decodable tags of the appropriate code (i.e., originally released in the Taku River).

Abundance of Adult Coho Salmon

A two-sample mark-recapture model will be used to estimate the number of adult coho salmon passing by Canyon Island. The appropriate abundance estimator will depend on the results of the aforementioned tests. If stratification is not needed, Chapman's (1951) version of Petersen's abundance estimator for closed populations (see Seber 1982) will be used:

$$\hat{N} = \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1 \tag{7}$$

where $\hat{N}$ = estimated number coho salmon, n_1 = number of marked coho salmon moving upstream of Canyon Island, n_2 = number of coho salmon inspected for marks in the Canadian commercial and test fisheries, and m_2 = number of marked coho salmon recaptured in the Canadian commercial and test fisheries.

If temporal-geographic stratification is not required but stratification by size or sex is (see Appendix A4), estimates for each stratum will be generated using equation (7) and these estimates summed to estimate total abundance and variance.

An estimate of the variance for $\hat{N}$ will be obtained through bootstrapping (Efron and Tibshirani 1993) according to methods in Buckland and Garthwaite (1991). The fate of the estimated $\hat{N}$ in the experiment will be divided into capture histories (similar to those described in Table 1 above) to form an empirical probability distribution (*epd*). A bootstrap sample of $\hat{N}$ will be drawn from the *epd* with replacement. From the resulting collection of re-sampled capture histories, n_1^*, n_2^*, m_2^*, and $\hat{N}^*$ will be calculated. A large number (B) of bootstrap samples will be so drawn. The approximate variance will be calculated as:

$$\text{var}(\hat{N}) = \frac{\sum_{b=1}^{B} (\hat{N}_b^* - \hat{\bar{N}}^*)^2}{B-1} \tag{8}$$

where $\hat{\bar{N}}^*$ is the average of the $\hat{N}_b^*$.

If geographic or temporal stratification is required, estimation of abundance will follow procedures described by Darroch (1961) using the computer program SPAS (Arnason et al. 1996). If stratification by size is required, size stratification will be conducted first and methods to correct for geographic or temporal capture heterogeneity will be applied independently to each size stratum. The contingency tables described in Appendix A5 will be further analyzed to identify: a) Event I strata (individual or contiguous groupings of temporal-geographic categories) where probability of recapture during the second event is homogeneous within strata and different between strata; and b) Event II strata where marked:unmarked ratios are homogeneous within strata and different between strata. Temporal categories generally will consist of groupings of sample data collected by week. Stratification will also be guided by environmental conditions encountered during data collection (river stage height and rainfall) and by previous experience gained when conducting mark-recapture experiments on this system. If the initial stratification does not result in an admissible maximum-likelihood (ML) estimate of abundance, further stratification may be necessary before an admissible estimate can be calculated. Nonadmissible estimates include failure of convergence of the ML algorithm in SPAS or convergence to estimators with estimated negative capture probabilities or estimated negative abundance within stratum. Goals in this case are always that observations within the pooled stratum should be as homogeneous as possible with respect to capture, migration, and recapture (Arnason et al. 1996).

A goodness of fit (GOF) test (provided in SPAS) comparing the observed and predicted statistics will indicate the adequacy of a stratified model. Once a stratification is identified that results in an admissible estimate of abundance, GOF will be evaluated. Further stratification, according to the guidelines described above, may be necessary to produce a model and abundance estimate with a satisfactory GOF. In general, the model selected will be that which provides an admissible estimate of abundance where no stratification guidelines are violated, no significant evidence of lack of fit is detected, and the smallest number of strata parameters are estimated for the model. This model will usually yield the smallest ML estimate of variance for the abundance estimate.

If the Darroch (1961) procedure is used to estimate abundance and the number of first and second event strata is not equal, the ML estimate of variance provided by the SPAS software will be used. If the number of first and second event strata is equal for the selected model, bootstrap methodology (Buckland and Garthwaite 1991) will be used to estimate variance and confidence intervals. There will be $(s)(t)$ capture histories for recaptured coho salmon, s capture histories for coho salmon marked but never recaptured, t histories for coho salmon captured upstream in the inriver fisheries without marks, and 1 history for all salmon never caught. These histories form a multinomial distribution with $(s+1)(t+1)$ cells. The frequency in these cells will sum to $\hat{N}$. A sample will be drawn from this multinomial distribution with replacement, and from this sample, equation 7 will be used to calculate a new estimate, $\hat{N}^*$, from the new sample. This process is repeated a large number of times, say B times, to produce an estimated empirical frequency distribution $\hat{F}^*$ for $\hat{N}$. The approximate variance for $\hat{N}$ is calculated as described in equation 8.

Darroch developed his model without a correction for bias caused by the substitution of statistics in the model. This bias can be large when sample sizes are small. The difference between $\hat{N}$ and $\overline{N}^*$ is a measure of this bias. Also, $\hat{F}^*$ will be used to develop approximate confidence intervals for $\hat{N}$; either the percentile or BC_a methods of Efron and Tibshirani (1993) will be used to develop these confidence intervals.

The estimated escapement is the difference between the estimated passage by Canyon Island (result of equation 7 or the Darroch model) and the inriver harvest above Canyon Island (tallies from the commercial and test fisheries in Canada). If it is assumed the inriver harvest is known without error, the estimated variance for spawning escapement will be the same as the variance estimated for the passage by Canyon Island.

Age and Sex Composition

Proportions by age or by sex of adult coho salmon and proportions by age for coho salmon smolt will be estimated by:

$$\hat{p}_j = \frac{n_j}{n} \tag{9}$$

and the associated variance approximated by:

$$v\hat{a}r[\hat{p}_j] = \frac{\hat{p}_j(1 - \hat{p}_j)}{n - 1} \tag{10}$$

where: p_j = the proportion in the population in group j;

n_j = the number in the sample of group j; and

n = the sample size.

Systematic selection of samples will promote proportional sampling and reduce bias from any inseason changes in age composition. For coho salmon smolts, statistics will be germane only to those fish captured. For adult coho salmon, statistics will be for the population. Because there is little (if any) relationship between size of adult and its freshwater age, no adjustment for any size-selective sampling should be necessary.

Testing the Hypothesis of Equal Survival Rates for Coho Salmon Smolts

All tags recovered from adults will be segregated by code into two groups corresponding to "smaller" and to "larger" smolts. The phrase "all tags" means all random and select tags recovered or voluntarily returned from marine fisheries and all tags recovered from Canyon Island and from freshwater commercial and test fisheries. From the sampling scenarios described above, we expect to recover about 600 tags. In past years, about half the smolts tagged were "smaller" smolt and half "larger". Assuming the same circumstance this year, approximately 12,250 "smaller" and 12,250 "larger" smolts should be tagged. About 300 (half) of the recoveries would be in each group under the null hypothesis of equal recovery rates. This expectation is based on there being no relationship between size of smolt and subsequent size of adult, which has proven to be the case with coho salmon. Without this smolt-to-adult link to size, there is no reason to believe that the probability of catching or sampling an adult is related to size as a smolt.

Power of the test was investigated with simulation. If p_s and p_l are the expected recovery rates for each group of fish, $p_s = p_l$ under the null hypothesis, and 300 tags would be recovered for each group as per scenarios described above. To represent alternative hypotheses, numbers of recovered tags were changed by ϕ as per 300 - ϕ for "smaller" fish and 300 + ϕ for "larger" such that $p_s = (300 - \phi)/12{,}250$ and $p_l = (300 + \phi)/12{,}250$. In the simulation a thousand pairs of random numbers of recovered tags were drawn with the first of each pair from the binomial distribution binom (12,250; p_s) and the second from binom (12,250; p_l). A χ^2 value was calculated for each pair and compared against the tabular value for this statistic when $\alpha = 0.05$. The number of pairs for which the calculated value was greater than the tabular correspond to the power of the test to detect a difference of $2\phi/(300+\phi)$ in the recovery rates solely due to differences in survival rates for the two groups. The value of ϕ was altered and the simulation repeated for each alteration to find a meaningful difference that could be detected in recovery rates with reasonable power. By meaningful difference, we mean a difference large enough to cause the discrepancy observed between freshwater age compositions as smolt and adults.

The same χ^2 test will be repeated on data once collected. If the null hypothesis is not rejected, there is no evidence that the estimated abundance would be biased from a combination of size-related differences in the capture and in the survival of smolt. However, given that freshwater age composition differs significantly between smolt and adult estimates, failure to reject the null hypothesis of equal recovery (survival) rates indicates that sampling of smolt is size-selective. The most likely reason for such sampling would be that larger, older smolts migrate after spring sampling has concluded. If the null hypothesis is rejected, the detected difference will be compared to the change in estimated age compositions to see if different survival rates could be the sole explanation.

SCHEDULES AND DELIVERABLES

Field activities for smolt will begin around April 15 pending weather, and extend through mid June. Field activities for returning coho salmon will commence approximately July 15 and extend through October 3. Field activities for returning Chinook salmon will begin approximately April 25 and extend through early September. All dates correspond to the year 2015.

Data will be edited and analysis will be initiated before the season is over. All smolt capture, CWT, trapping effort, and length data for the 2015 field season will be summarized and provided to the CF Tag Lab by August 1, 2015.

REPORTS

Data will be reported in a Fishery Data Series report and submitted as a draft on March 1, 2017. This report will cover all 2015 coho smolt data, harvest contributions, and the escapement in 2016. Excerpts of the above report will be included in the annual report of the PSC joint Transboundary Technical Committee.

Final smolt, harvest and other parameters and data for Chinook salmon from the 2013 brood year will be reported in a Fishery Data Series report submitted by May 1, 2021.

RESPONSIBILITIES

Jeff Williams, FB II, Project Leader (ADF&G-SF smolt and adult escapement). Works with Ed Jones (ADF&G) on field operations, data analysis, and report writing. Supervises smolt project; edits, analyzes, and reports data; assists with field work; maintains near-daily radio or telephone contact with field camp; arranges logistics with field crew and expeditor. Writes smolt sampling section of operational plan, assures that it is followed or modified appropriately with consultation with Jones. Is coauthor on final report with Jones and assures that the operational plans are followed or modified appropriately with consultation with Jones, Andel, and the fish wheel crew leader.

Ed Jones, Fish and Game Coordinator, Project Leader (ADF&G-SF smolt and adult escapement). Sets up all major aspects of smolt project, including planning, budget, sample design, permits, equipment, personnel, and training. Works with Jeff Williams (ADF&G) and Jim Andel (ADF&G) with respect to adult operational plans. Reviews operational plan and provides operational details. Is coauthor on final report with Williams and reviews and assists with data analysis and final report.

Jim Andel, FB II, Project Leader (ADF&G-CF Canyon Island). Sets up all major aspects of adult Chinook and coho salmon operations at Canyon Island, in cooperation with Jones and Williams, including planning, budgeting, implementation and data transfer, analysis and summarization. Reviews operational plan and agrees on sampling protocols for Canyon Island, test fisheries and Canadian commercial fisheries. Implements all field operations at Canyon Island and works closely with field personnel to see that project objectives and sampling protocols are followed. Provides training, as needed, to field crew for ADF&G at Canyon Island. Provides Chinook and coho salmon CWT data, forms and heads to Jones or Williams on a weekly basis from Canyon Island and the test fisheries; provides ASL data from Chinook to Jones/Williams on a weekly basis.

Sarah Power, Biometrician. Provides input to, edits and approves sampling design. Coauthors operational plan and provides biometric details, including any changes or statistical techniques needed to provide precise and unbiased estimates for this project. Coauthors and assists with data analysis and final report.

Nathan Frost, FWT III. This position serves as crew leader of the smolt camp tagging operations for juvenile Chinook and coho salmon, and collection and recording of all associated biological and catch-effort data with consultation from Williams. Ensures that the operational plan is followed to the extent possible, and implements inseason changes as authorized. Determines work schedules and assigns tasks to smolt crew members with Williams. Will be in charge of running one of the trap lines. Tags fish, collects samples, and records data according to operational plan. Performs tagging and sampling summaries, and error-checks CWT tagging data daily. Monitors crew performance and corrects or trains the crew as needed. Performs maintenance on all sampling and camp equipment. Ensures pertinent portions of State SOP, such as safety and time reporting, are followed. Maintains near-daily contact with Douglas office for safety, data, and logistical needs. Does inventory at end of field season.

Lee Close, FWT III. Will be in charge of running one of the trap lines and adjusting trap placements accordingly to maximize catches. Is responsible for daily operation and cleaning of the Mark IV coded wire tagging machines associated with smolt tag and release operations. Will measure and weigh coho smolt and record data in Rite-in-the-Rain® book. Will measure Chinook smolt and record lengths and weights in a Rite-in-the-Rain® book. Works closely with crew leader to follow protocol and quality control while maximizing smolt tagging operational efficiency. Will assist in all aspects of field operations, including safe operation of riverboats and all other equipment, tagging, data collection, data recording, and general field camp duties including keeping camp and field equipment neat and orderly. Responsible for fish handling to prevent mortalities or injuries. Will assist with inventory at the end of the season.

Evan Fritz, FWT II. This position is responsible for assisting in all aspects of smolt field operations, including safe operation of riverboats and all other equipment, tagging, data collection and general field camp duties including keeping camp and field equipment neat and orderly. Will be clipper or tagger in tagging shed as needed.

Tory Rhoads, FWT II. This position is responsible for assisting in all aspects of smolt field operations, including safe operation of riverboats and all other equipment, tagging, data collection and general field camp duties including keeping camp and field equipment neat and orderly. Will be clipper or tagger in tagging shed as needed.

Mike Lafollette, Fishery Biologist I. This position serves as crew leader on the Canyon Island fish wheel and gillnet tagging operations for adult Chinook and coho salmon, and collection and recording of all associated biological and catch/effort data, including CWT recovery. Ensures that the operational plan is followed to the extent possible, and implements inseason changes as authorized. Determines work schedules and assigns tasks to fish wheel crew members. Tags fish, collects samples, and records data according to operational plan. Performs tagging and sampling summaries, and error-checks fish wheel and gillnet data daily. Monitors crew performance and corrects or trains the crew as needed. Performs maintenance on all sampling and camp equipment. Ensures pertinent portions of State SOP, such as safety and time reporting, are followed. Oversees camp logistics, such as plane flights, fuel, groceries, and spare parts. Maintains near-daily contact with Douglas office for safety, data, and logistical needs. Does inventory at end of field season. Will consult with Williams regarding the efficiency of work and will provide input on changes necessary to improve operations. Turns in all data to project biologist and writes preliminary performance evaluations for the crew.

Travis Orient, FWT III. This position is responsible for being second in charge of fish wheel operations for tagging and sampling adult salmon, and assists in all aspects of the project. Will be under direct supervision of the Canyon Island crew leader and will be relied upon for expertise gained from previous experience participating in the daily sampling and activities of adult tag and recovery operations. Will consult with Williams regarding the efficiency of work and will provide input on changes necessary to improve operations. May assist with smolt camp operations during startup.

Zane Chapman, FWT II. This position is responsible for working on the fish wheels for tagging and sampling adult salmon, and assists in all aspects of the project. Will be under direct supervision of the Canyon Island crew leader. Will consult with Williams regarding the efficiency of work and will provide input on changes necessary to improve operations. May assist with smolt camp operations during startup.

Dave Dreyer, FWT IV. This position serves as crew leader on the drift gillnet tagging operations for adult Chinook, and collection and recording of all associated biological and catch/effort data, including CWT recovery. Ensures that the operational plan is followed to the extent possible, and implements inseason changes as authorized. Determines work schedules and assigns tasks to drift gillnet crew members. Tags fish, collects samples, and records data according to operational plan. Performs tagging and sampling summaries, and error-checks drift gillnet data daily. Monitors crew performance and corrects or trains the crew as needed. Performs maintenance on all sampling equipment. Ensures pertinent portions of State SOP, such as safety and time reporting, are followed. Will consult with Williams regarding the efficiency of work and will provide input on changes necessary to improve operations.

Michael Enders, FWT III. This position is responsible for running a drift gillnet for tagging adult Chinook salmon near Wright River and will assist in all aspects of this project including fish wheel work when available.

Norm Miller, FWT IV. This position is responsible for being the project expeditor for the smolt and fish wheel crews in April, May and June. Will be responsible for purchasing supplies and delivering them to the air service, as well as loading and unloading of supply planes. Will coordinate logistics with Williams and both crew leaders. Will also participate in the field on both projects when necessary.

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APPENDIX A

On the surface, Petersen's estimator for closed populations seems appropriate for estimating smolt abundance of coho salmon in the context of using coded wire tags (CWTs). A sample of smolts is marked and tagged one year, and a sample of adults is inspected for marks in the following year. During the year at sea the population is open to mortality, but because of their life history, the population is closed to recruitment. If all other conditions are met, the mark-recapture experiment should provide an asymptotically accurate estimate of the abundance of smolts.

One condition that is not met for the experiment on the Taku River from 2001–2002 is that each smolt must have an equal probability of being marked or inspected for marks regardless of their size. Smaller smolt were less likely to be captured in 2001 than were larger smolt. Since smaller smolt suffered a higher mortality rate than did larger smolt, smaller smolt also had less of a chance of being recaptured as adults. Ignoring these circumstances produces an estimate of abundance that is biased low.

Under these circumstances, abundance of coho salmon smolt can be estimated accurately using a weighted variant of Chapman's modification of Petersen's closed-population estimator:

$$\hat{N} = \frac{(\hat{A}M_1 + M_2 + 1)(C+1)}{\hat{A}(R_1 + \hat{\pi}R_3) + R_2 + (1-\hat{\pi})R_3 + 1} - 1 \qquad \text{(A1.1)}$$

where M is the number of smolts marked by size group (1 = smaller 75–85 mm FL, 2 = larger >85 mm FL) in 2001, C the number of adults in 2002 inspected for marks, R the subset of C with marks representing a size group of smolts (3 = group unknown), A is the ratio of the catchability coefficients for larger (>85 mm FL) to smaller (≤ 85 mm FL) smolt in 2001, and π is the fraction of adults in 2002 that were smolts 70–85 mm FL in 2001. The estimate A is used to adjust for differences in catchability in 2001 such that A > 1, when larger smolt are more catchable and < 1 when larger smolt are less catchable. Because some recaptured fish are not sacrificed to find tags or some marked adults do not contain tags, π is used to assign recaptured fish of unknown pedigree to the appropriate smolt size group. An estimate of π is:

$$\hat{\pi} = \frac{T_1}{T_1 + T_2} \qquad \text{(A1.2)}$$

where T is the number of all tags representing a smolt size group recovered or recaptured from adult salmon regardless of how or where recovered or recaptured.

Evidence for smolts not having equal probability of being marked or inspected for marks regardless of size can be found in the recovery rates of CWTs. Recovery of tags in 2002 from both smolt groups indicates that smolt in the larger-size group survived about 54% better than did smaller smolt (P<0.0001, $\chi^2 = 20.1$, df = 1):

Smolt size group	***M***	***T***	Recovery rate
Smaller	23,285	163	0.0070215
Larger	27,250	294	0.1078899

Vincent-Lang (1993) has shown that coho salmon smolts marked as in this project and handled competently suffer no detectable mortality from the experience. Also, there is no reason to believe that capture rates for adults is influenced by the code on a tag imbedded deep within its cartilage. For these reasons, the differences in recovery rates is most likely due to natural differences in survival rates. This difference means that smolts in the smaller-size group were less likely to be inspected for marks as adults than larger smolts.

Further calculations based on estimates of relative age composition of smolts and adults show that catchability of smolt in the larger-size group was about seven and a half times greater than the catchability of smaller smolt in 2001. If $\hat{p}$ is the estimated fraction of all <u>adults</u> that are of age 1-freshwater, if $\hat{\phi}_1$ is the estimated fraction of <u>smolt</u> in the smaller-size group that were age 1-freshwater, and if $\hat{\phi}_2$ is the estimated fraction of <u>smolt</u> in the larger-size group that were age 1-freshwater, an estimate of the ratio of catchability coefficients for larger to smaller smolt is:

$$\hat{A} = \frac{T_2(\hat{\phi}_2 - \hat{p})}{T_1(\hat{p} - \hat{\phi}_1)} \tag{A1.3}$$

(see Appendix Addendum A1.1 for derivation of eq. A1.3). From Appendix Table A1.1, $\hat{\phi}_1$ = 228/242 = 0.9421 and $\hat{\phi}_2$ = 129/284 = 0.4542. Of the 1,112 adults sampled at Canyon Island in 2002, 943 were age 1.1, making $\hat{p}$ = 943/1112 = 0.8480. Given that T_1 = 163 and T_2 = 294 in 2002, $\hat{A}$ = 7.55. Simulations (see below) indicate that this estimated rate is statistically different than 1.

Plugging statistics given above into eq. A1.1 and noting that $\hat{\pi}$ = 163/(163+294) = 0.357, estimated abundance is:

$$2{,}718{,}816 = \frac{([(7.55)(23{,}285 + 27{,}250 + 1][3{,}765 + 1]}{[(7.55(16 + \{0.357\}40) + 26 + \{1 - 0.357\}40) + 1]} - 1$$

Appendix Table A1.1.–Age composition of coho salmon smolt marked with coded wire and sampled for age in the Taku River in 2001.

	Age-1.1	Age-2.1	Total
Small	228	14	242
Large	129	155	284
Total	357	169	526

with R_1 = 16, R_2 = 16, R_3 = 40, and C = 3,765. The pooled estimate of abundance from the standard modification of Petersen's estimator is 2,292,994, about 16% less.

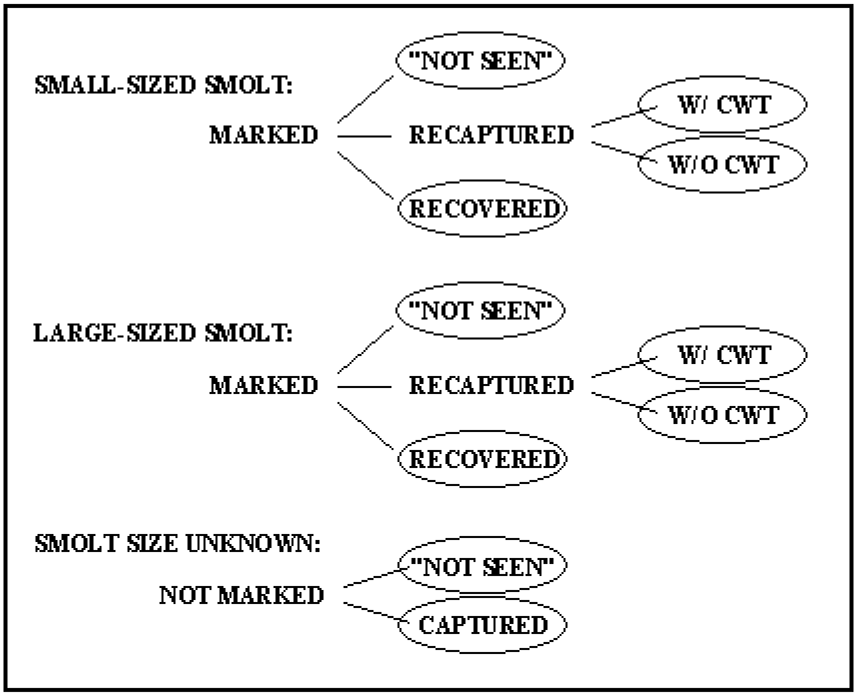
Variance and relative statistical bias in the estimator (eq. A1.1) was estimated with bootstrap procedures described in general by Buckland and Garthwaite (1991). Each bootstrap sample was drawn randomly with replacement from the capture histories of the $\hat{N}$ smolt in the "virtual" population (Appendix Figure A1.1). From the bootstrap sample a new estimate of smolt abundance $\hat{N}'$ was calculated. Then the process was repeated two hundred times to create the frequency distribution $\hat{F}'(\hat{N}')$. At the end of the iterations, the following statistics were calculated:

$$\overline{N}' = \frac{\sum_{b=1}^{200} \hat{N}'_{(b)}}{200} \qquad \text{(A1.4a)}$$

$$\text{var}(\hat{N}) = \frac{\sum_{b=1}^{200} (\hat{N}'_{(b)} - \overline{N}')^2}{200 - 1} \qquad \text{(A1.4b)}$$

$$\text{Estimated Relative Bias} = \frac{\overline{N}' - \hat{N}}{\hat{N}}(100) \qquad \text{(A1.4c)}$$

The 10 capture histories are provided in Appendix Table A1.2. Bootstrap estimates $\hat{\phi}'_1$ were obtained from a binomial distribution with parameters $M'_1/96$ and $\hat{\phi}_1$ (about 1 of every 96 captured smolt were sampled to determine age in 2001); estimates $\hat{\phi}'_2$ were estimated in the same manner. Bootstrap estimates $\hat{p}'$ were obtained from a binomial distribution with parameters 1112 and $\hat{p}$.



Appendix Figure A1.1.–Capture histories (in ovals) concerning smolts in the population emigrating from the Taku River in 2001.

Results of the bootstraps simulations are as follows. The bootstrap estimate $\overline{N}' = 2{,}770{,}138$ indicating an estimate of relative statistical bias in $\hat{N}$ less than 2%. The bootstrap estimate for the standard error of $\hat{N}$ is 364,867 for a CV just over 13.4%. Simulated estimates of $\hat{A}$ had a low of 4.069, a standard error of 2.195, and indicated a relative bias in $\hat{A}$ of just over 29%. The BASIC program SMLTTAKU.BAS was used to conduct the simulations.

Appendix Table A1.2.–Relationships among history variables, capture histories, and model variables in bootstrap simulations.

Program Variable	Capture History	Model Variables	Values
n(1)	Not marked, not seen	$\hat{N} - M_1 - M_2 - C + R_1 + R_2 + R_3$	
n(2)	Marked, not seen - Smaller Smolt	$M_1 - T_1$	23,250 - 163 = 23,122
n(3)	" " - Larger Smolt	$M_2 - T_2$	23,285 - 294 = 26,956
n(4)	Marked, recaptured - Smaller Smolt w/ CWT	R_1	16
n(5)	" " - Larger Smolt w/ CWT	R_2	26
n(6)	" " - Smaller Smolt w/o CWT	$\hat{\pi} R_3$	0.357(40) = 14
n(7)	" " - Larger Smolt w/o CWT	$(1-\hat{\pi}) R_3$	(1 - 0.357)40 = 26
n(8)	Marked, recovered - Smaller Smolt	$T_1 - R_1 - \hat{\pi} R_3$	163 - 16 - 14 = 133
n(9)	" " - Larger Smolt	$T_2 - R_2 - (1-\hat{\pi}) R_3$	294 - 26 - 26 = 242
n(10)	Not Marked, captured	$C - R_1 - R_2 - R_3$	3765 - 16 - 26 - 40 = 3683

Appendix Addendum A1.1–Estimation of the ratio of catchabilities

The fraction p of adults with 1-freshwater age can be expressed as:

$$p = \frac{N_1\phi_1 S_1 + N_2\phi_2 S_2}{N_1 S_1 + N_2 S_2} = \frac{N_1\phi_1 S_1 + N_2\phi_2 B\mathrm{S}_1}{N_1 S_1 + N_2 B S_1} = \frac{N_1\phi_1 + N_2\phi_2 B}{N_1 + N_2 B}$$

where N is smolt number by smolt size group, S their survival rate, ϕ the fraction of the smolt group comprised of smolt age 1-freshwater, and B is the ratio of survival rates S_2/S_1. This relationship simplifies to:

$$\frac{N_1}{N_2} = \frac{B(\phi_2 - p)}{(p - \phi_1)}$$

If α is the capture rate of smolts, then $M_1 = \alpha_1 N_1$ and $M_2 = \alpha_2 N_2$, and:

$$\frac{N_1}{N_2} = \frac{M_1}{M_2}\frac{\alpha_2}{\alpha_1} = \frac{B(\phi_2 - p)}{(p - \phi_1)}$$

If A is the ratio of catchability for the two groups of smolts, then $A = \alpha_2 / \alpha_1$ since fishing effort by definition is equal for both groups. Substitution creates:

$$A = \frac{M_2 B(\phi_2 - p)}{M_1(p - \phi_1)}$$

A naïve estimate of A is therefore:

$$\hat{A} = \frac{M_2 \hat{B}(\hat{\phi}_2 - \hat{p})}{M_1(\hat{p} - \hat{\phi}_1)}$$

Noting that the estimate for the ratio of survival rates is:

$$\hat{B} = \frac{T_2}{M_2}\frac{M_1}{T_1}$$

A simpler estimate for A is:

$$\hat{A} = \frac{T_2(\hat{\phi}_2 - \hat{p})}{T_1(\hat{p} - \hat{\phi}_1)}$$

Appendix A 2.–Statistics from 2014 used to link the number of coho salmon smolt to tag in 2015 with the ultimate relative precision of the estimated harvest from adults returning to the Taku River in 2016.

ϕ = 0.30 (average all fisheries); θ= 0.0071(x 926,067 smolt corresponds to 6,856 smolt tagged); $G(\theta^{-1})$ = .002)

Stratum	Stat/Bi-week	$\widehat{N}_i$	n_i	m_i	λ_i	$\hat{r}_{i,j}$	φ_i	$G(p_i)$	$SE(r_i)$
Troll NW 4	29-32	807,735	195,267	3	0.9809	2,428	24%	0.333	1,403
Troll NW 5	34-38	694,353	131,225	9	0.9892	9,238	19%	0.111	3,098
Troll SW 5	33	136,369	59,847	1	0.9681	452	44%	0.998	451
Seine SE	34	23,480	5,904	1	0.9870	773	25%	0.999	616
Sport Sitka	16	11,561	3,714	1	0.9688	617	32%	0.998	211
Sport Elfin Cove	16	621	621	1	0.9091	211	100%	0.995	211
Sport Elfin Cove	17	652	625	1	1.0000	200	96%	0.995	200
Sport Juneau	15	2,092	466	1	1.0000	861	22%	0.999	861
Sport Juneau DE, DT, MB	16	2,802	1,734	2	0.8571	724	62%	0.499	511
Sport Juneau	17	2,864	527	1	1.0000	1,043	18%	0.999	1,042
Drift GN 111	28	294	146	1	1.0000	386	50%	0.997	386
Drift GN 111	33	2,672	558	2	1.0000	1,838	21%	0.499	1,300
Drift GN 111	34	4,301	926	2	1.0000	1,783	22%	0.499	1,261
Drift GN 111	35	4,510	516	1	1.0000	1,677	11%	0.999	1,677
Drift GN 111	36	9,390	3,122	6	1.0000	3,463	33%	0.166	1,418
Drift GN 111	37	15,600	3,278	12	1.0000	10,959	21%	0.083	3,190
Drift GN 111	38	9,225	2,714	8	1.0000	5,218	29%	0.125	1,854
Drift GN 111	39	2,394	309	2	1.0000	2,973	13%	0.500	2,104
Drift GN 115	36	6,748	4,053	1	0.9744	328	60%	0.997	327
Drift GN 115	37	6,506	3,170	2	0.9583	822	49%	0.499	581
Drift GN 115	38	10,936	4,694	3	1.0000	1,341	43%	0.333	775
Drift GN 115	40	2,714	1,535	4	1.0000	1,357	57%	0.249	679
$RP[\hat{r}_j]$ = 26.3%		1,757,819	424,951	65		48,682	24%		6,536

Note: as examples, "Troll, NW4" are statistics from the troll fishery from the Northwest Quadrant during Period 4; "Seine SE" are statistics from the seine fishery in the Southeast Quadrant; "Sport – Juneau DE" are statistics from the Juneau marine sport fishery that were "derby entered"; "Sport – Juneau DT" are statistics from the Juneau marine sport fishery that were "derby take home"; "Drift GN 111" are statistics from the drift gillnet fishery in District 111.

Appendix A 3.–Statistics used to link the number of Chinook salmon smolt to tag in 2015 with the ultimate relative precision of the estimated harvest from adults returning to the Taku River from 2016 to 2020.

ϕ = 0.40 (average all fisheries); θ = 0.016 (x 1,800,000 smolt corresponds to 29,000 smolt tagged); $G(\theta^{-1})$= 63.069

Stratum	Age	Stat/Bi-Week	$\hat{N}_i$	$V[\hat{N}_i]$	n_i	m_i	λ_i	$\hat{r}_{ij}$	ϕ	$G(p_j)$	$G(\hat{N}_i)$	$SE(r_j)$
Drift GN 111	1.2	19	1,244		729	4	1.0000	474	59%	0.223		230
Drift GN 111	1.2	20	1,844		876	3	0.9091	368	48%	0.391		233
Drift GN 111	1.2	21	4,399		2,475	5	1.0000	525	56%	0.210		248
Drift GN 111	1.2	22	5,372		2,969	2	1.0000	216	55%	0.521		157
Drift GN 111	1.2	23	4,321		1,787	3	1.0000	459	41%	0.327		267
Drift GN 111	1.2	24	3,016		970	2	1.0000	328	32%	0.590		253
Drift GN 111	1.2	27	578		213	1	0.9412	183	37%	0.983		181
Troll NW	1.3	19	91,991		30,212	3	0.9927	487	33%	0.392		309
Troll NE	1.3	20	17,009		11,322	3	0.9954	240	67%	0.390		152
Sport - Juneau	1.3	9	623	15,022	138	1	1.0000	383	22%	0.735	0.039	332
Sport - Juneau	1.3	11	1,015	31,883	190	1	0.9444	480	19%	0.735	0.031	415
Drift GN 111	1.3	21	5,507		3,149	4	1.0000	396	57%	0.274		212
Drift GN 111	1.3	22	9,506		5,004	6	0.9831	691	53%	0.174		299
Drift GN 111	1.3	23	7,601		3,280	3	1.0000	368	43%	0.391		233
Drift GN 111	1.3	26	761		211	3	1.0000	573	28%	0.392		363
Drift GN 111	1.3	27	809		308	1	0.9524	219	38%	0.783		194
Troll NW	1.4	19	127,173		50,631	3	0.9905	503	40%	0.313		287
Troll NE	1.4	20	14,717		4,586	4	0.9535	935	31%	0.224		455
Sport - Juneau	1.4	9	297	6,974	53	1	1.0000	445	18%	0.786	0.079	399
Drift GN 111	1.4	22	1,627		1,087	3	1.0000	297	67%	0.312		169
Drift GN 111	1.4	24	858		319	3	1.0000	534	37%	0.313		304
Drift GN 111	1.4	25	2,123		599	1	1.0000	281	28%	0.784		250
Drift GN 111	1.4	29	1,241		373	1	1.0000	264	30%	0.784		234
RP[$\hat{r}_j$] = 27%			303,632	53,879	121,481	61		9,650	40%			1,344

Appendix A 4.–Detection of size and/or sex selective sampling during a two-sample mark recapture experiment and its effects on estimation of population size and population composition.

Size selective sampling: The Kolmogorov-Smirnov two sample test (Conover 1980) is used to detect significant evidence that size selective sampling occurred during the first and/or second sampling events. The second sampling event is evaluated by comparing the length frequency distribution of all fish marked during the first event (M) with that of marked fish recaptured during the second event (R) by using the null test hypothesis of no difference. The first sampling event is evaluated by comparing the length frequency distribution of all fish inspected for marks during the second event (C) with that of R. A third test that compares M and C is then conducted and used to evaluate the results of the first two tests when sample sizes are small. Guidelines for small sample sizes are <30 for R and <100 for M or C.

Sex selective sampling: Contingency table analysis (Chi^2-test) is generally used to detect significant evidence that sex selective sampling occurred during the first and/or second sampling events. The counts of observed males to females are compared between M&R, C&R, and M&C using the null hypothesis that the probability that a sampled fish is male or female is independent of sample. If the proportions by gender are estimated for a sample (usually C), rather an observed for all fish in the sample, contingency table analysis is not appropriate and the proportions of females (or males) are then compared between samples using a two sample test (e.g. Student's t-test).

M vs. R	**C vs. R**	**M vs. C**
Case I:		
Fail to reject H_o	Fail to reject H_o	Fail to reject H_o

There is no size/sex selectivity detected during either sampling event.

Case II:

Reject H_o	Fail to reject H_o	Reject H_o

There is no size/sex selectivity detected during the first event but there is during the second event sampling.

Case III:

Fail to reject H_o	Reject H_o	Reject H_o

There is no size/sex selectivity detected during the second event but there is during the first event sampling.

Case IV:

Reject H_o	Reject H_o	Either result possible

There is size/sex selectivity detected during both the first and second sampling events.

Evaluation Required:

Fail to reject H_o	Fail to reject H_o	Reject H_o

Sample sizes and powers of tests must be considered:

A. If sample sizes for M vs. R and C vs. R tests are not small and sample sizes for M vs. C test are very large, the M vs. C test is likely detecting small differences which have little potential to result in bias during estimation. *Case I* is appropriate.

B. If a) sample sizes for M vs. R are small, b) the M vs. R p-value is not large (~0.20 or less), and c) the C vs. R sample sizes are not small and/or the C vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the second event which the M vs. R test was not powerful enough to detect. *Case I* may be considered but *Case II* is the recommended, conservative interpretation.

C. If a) sample sizes for C vs. R are small, b) the C vs. R p-value is not large (~0.20 or less), and c) the M vs. R sample sizes are not small and/or the M vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the first event which the C vs. R test was not powerful enough to detect. *Case I* may be considered but *Case III* is the recommended, conservative interpretation.

D. If a) sample sizes for C vs. R and M vs. R are both small, and b) both the C vs. R and M vs. R p-values are not large (~0.20 or less), the rejection of the null in the M vs. C test may be the result of size/sex selectivity during both events which the C vs. R and M vs. R tests were not powerful enough to detect. *Cases I, II, or III* may be considered but *Case IV* is the recommended, conservative interpretation.

Case I. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated after pooling length, sex, and age data from both sampling events.

Case II. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the first sampling event without stratification. If composition is estimated from second event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the M vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case III. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the second sampling event without stratification. If composition is estimated from first event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the C vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case IV. Data must be stratified to eliminate variability in capture probability within strata for at least one or both sampling events. Abundance is calculated using a Petersen-type model for each stratum, and estimates are summed across strata to estimate overall abundance. Composition parameters may be estimated within the strata as determined above, but only using data from sampling events where stratification has eliminated variability in capture probabilities within strata. If data from both sampling events are to be used, further stratification may be necessary to meet the condition of capture homogeneity within strata for both events. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance.

If stratification by sex or length is necessary prior to estimating composition parameters, then an overall composition parameters (p_k) is estimated by combining within stratum composition estimates using:

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}_\Sigma}\hat{p}_{ik} \text{ ; and,} \tag{1}$$

$$\hat{V}\left[\hat{p}_k\right] \approx \frac{1}{\hat{N}_\Sigma^2}\sum_{i=1}^{j}\left(\hat{N}_i^2\hat{V}\left[\hat{p}_{ik}\right] + \left(\hat{p}_{ik} - \hat{p}_k\right)^2\hat{V}\left[\hat{N}_i\right]\right). \tag{2}$$

where:

	j	=	the number of sex/size strata;
	$\hat{p}_{ik}$	=	the estimated proportion of fish that were age or size *k* among fish in stratum *i*;
	$\hat{N}_i$	=	the estimated abundance in stratum *i*; and,
	$\hat{N}_\Sigma$	=	sum of the $\hat{N}_i$ across strata.

Appendix A 5.–Tests of consistency for the Petersen estimator (from Seber 1982, page 438).

Tests of consistency for petersen estimator

Of the following conditions, at least one must be fulfilled to meet assumptions of a Petersen estimator:

1. Marked fish mix completely with unmarked fish between events;
2. Every fish has an equal probability of being captured and marked during event 1; or,
3. Every fish has an equal probability of being captured and examined during event 2.

To evaluate these three assumptions, the chi-square statistic will be used to examine the following contingency tables as recommended by Seber (1982). At least one null hypothesis needs to be accepted for assumptions of the Petersen model (Bailey 1951, 1952; Chapman 1951) to be valid. If all three tests are rejected, a temporally or geographically stratified estimator (Darroch 1961) should be used to estimate abundance.

I.-Test For Complete Mixing[a]

Area/Time	Area/Time Where Recaptured				Not Recaptured
Where Marked	**1**	**2**	**…**	**t**	$(n_1\text{-}m_2)$
1					
2					
…					
s					

II.-Test For Equal Probability of capture during the first event[b]

	Area/Time Where Examined			
	1	**2**	**…**	**t**
Marked (m_2)				
Unmarked $(n_2\text{-}m_2)$				

III.-Test for equal probability of capture during the second event[c]

	Area/Time Where Marked			
	1	**2**	**…**	**s**
Recaptured (m_2)				
Not Recaptured $(n_1\text{-}m_2)$				

[a] This tests the hypothesis that movement probabilities (θ) from time or area i (i = 1, 2, ...s) to section j (j = 1, 2, ...t) are the same among sections: H_0: $\theta_{ij} = \theta_j$.

[b] This tests the hypothesis of homogeneity on the columns of the 2-by-t contingency table with respect to the marked to unmarked ratio among time or area designations: H_0: $\Sigma_i a_i \theta_{ij} = kU_j$, where k = total marks released/total unmarked in the population, U_j = total unmarked fish in stratum j at the time of sampling, and a_i = number of marked fish released in stratum i.

[c] This tests the hypothesis of homogeneity on the columns of this 2-by-s contingency table with respect to recapture probabilities among time or area designations: H_0: $\Sigma_j \theta_{ij} p_j = d$, where p_j is the probability of capturing a fish in section j during the second event, and d is a constant.

APPENDIX B

Appendix B 1.–Data form to record daily CWT tagging results.

CWT DAILY TAGGING, ADF&G Division of Sport Fish

Location: Taku River
Species: Chinook
Year: 2015

Date: ________________

Tag code: ________________

Machine Serial Number: ________________

	a. Number of fish tagged	___
	b. Post tagging mortalities	___
	c. Total tagged fish released (a-b)	___
Recaptures:		
	d. Number with CWTs	___
	e. Total number of recaptures	___
24 hour tag retention:		
	f. Number with CWTs	___
	g. Total number tested	___
	h. Short-term retention % (f/g)	___
	i. Adjusted tagged and released (h*c)	___
	Cumulative tagged and released:	___

Comments

Appendix B 2.–Data form to record daily environmental conditions.

DAILY ENVIRONMENTAL CONDITIONS, ADF&G Division of Sport Fish

Location: Taku River
Year: 2015

	Air Temp		Water			
Date	Min	Max	Temp	Depth	Precipitation	General Weather Condition

Appendix B 3.–A representative portion of the data form for recording salmon smolt length, weight, and scale samples.

SALMON SMOLT LENGTH, WEIGHT AND SCALE SAMPLES

LOCATION____________________________________ YEAR________ PAGE ___ of ___

Samplers____________________________________

Date	Fish #	Slide	Scale #	Length	Wt.	Age	Comments	Date	Fish #	Slide	Scale #	Length	Wt.	Age	Comments
			1								1				
			2								2				
			3								3				
			4								4				
			1								1				
			2								2				
			3								3				
			4								4				
			1								1				
			2								2				
			3								3				
			4								4				
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			3								3				
			4								4				
			1								1				
			2								2				
			3								3				
			4								4				
			1								1				
			2								2				
			3								3				
			4								4				

Appendix B 4.–Data form for recording Canyon Island adult salmon fishing effort and physical data.

FISHING EFFORT

Date	Wheel 1 Hours Fished	Wheel 1 RPM	Wheel 2 Hours Fished	Wheel 2 RPM	Gillnet Hours Fished	Water Temp ^{o}C	Water Level ft	Weather	Comments

Appendix B 5.–Data form for recording numbers of fish caught and tagged during each check of the Canyon Island fish wheels and total gillnet time.

WHEEL SAMPLING PERIOD FORM

Date

		Sockeye		Chinook		Coho		Chum		Pink	DV	Steelhead
Time		Caught	Tagged	Caught	Tagged	Caught	Tagged	Caught		Caught	Caught	Caught
	FW1											
	FW2											
	Subtotal											
	FW1											
	FW2											
	Subtotal											
	FW1											
	FW2											
	Subtotal											
	GILLNET											
Daily	FW1											
Total	FW2											
	Total											

Appendix B 6.–Data form used to record GPS and juvenile capture data.

Date: ____________ GPS Unit #: ____________ Location: Lower Taku River

Observers: ____

Comments: ____

____

Waypoint number	Date	Waypoint accuracy (m)	Number of traps	Name of trapping area	Soak time (hr)	Catch		Habitat (see below)	River left, right, or middle	Habitat cause	Comments
						Chinook	Coho				
26	*Apr 8*	*8*	*2*	*Dale Hole*	*24*	*25*	*45*	*Pool/Scour*	*Left*	*Wood stump*	*8 dolly varden, 2 sculpin*
27	*Apr 8*	*8*	*4*	*The Cut*	*24*	*12*	*20*	*Pool/slough*	*Left*	*Large boulder*	*Saw school of eulachon; caught 3 dolly varden*
28	*Apr 8*	*11*	*1*	*Al's Bar*	*24*	*16*	*15*	*Pool/backwater*	*Right*	*Sandbar*	
32	*Apr 9*	*15*	*2*	*Middle Max*	*12*	*6*	*3*	*Pool/backwater*	*Middle*	*Sandbar*	*Birds everywhere 2 sculpin*

Habitat: Macro is either **pool** or **fast water**; meso is either a **backwater**, **scour**, or **slough** as part of macro **pool** or **glide**, **riffle**, **cascade** as part of macro **fast water**.